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**Final Report**

**submitted to**

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GEORGE C. MARSHALL SPACE FLIGHT CENTER, ALABAMA 35812**

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**Drop Tube Research**

**by**

**Gary L. Workman Ph.D.  
Principal Investigator**

**Materials Processing Laboratory  
Center for Automation & Robotics  
University of Alabama in Huntsville  
Huntsville, Alabama 35899**

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## **1.0 Introduction**

This report covers the activities performed in the Drop Tube Study which The University of Alabama in Huntsville designed, fabricated and performed various low gravity experiments in materials processing from November 1, 1991 through October 30, 1992. During the performance of this contract the utilization of these ground-based containerless processing facilities has been instrumental in providing the opportunity to determine the feasibility of performing a number of solidification experiments in a simulated space environment, without the expense of a space-based experiment.

A number of periodic reports have been given to the TCOR during the course of this contract hence this final report is meant only to summarize the many activities performed and not redundantly cover materials already submitted.

## **2.0 Tasks Accomplished**

2.1.1. In collaboration with scientists from MSFC, universities, and industry, UAH has defined, developed, and conducted materials processing experiments in low gravity using the Drop Tube at MSFC and the KC-135 aircraft at Ellington Field. This effort has included the defining of experimental equipment, and equipment, experiment-facility integration requirements, building/assembling the necessary experiment apparatus, and conducting experiments which will contribute to the knowledge base for commercialization of materials processing in low gravity. UAH has also performed the logistical support needed to execute the experimentation, and the necessary sample preparation, metallography analysis/interpretation and physical properties measurements of processed samples. UAH has interfaced with designated MSFC scientists and project representatives who provide Center policy, programmatic requirements and goals, priorities, and scientific and technical advice.

2.1.1 UAH has continued to perform innovative materials research in the low gravity, containerless environment of the MSFC 105 meter Drop Tube Facility. The Drop Tube has worked daily to perform drop experiments, build up a number of innovations in experimental hardware for drops and provide some maintenance on existing instrumentation in order to perform our research. Dr Mike Robinson has provided the leadership for MSFC in overseeing this facility and its function within NASA's materials processing program. Tom Rathz has led the UAH activities at the Drop Facilities and, although he works full time

under the Principal Investigator for UAH, Tom has also worked quite closely with Dr. Robinson in determining and meeting scientific objectives at the Drop Facilities.

Current experimental hardware which is still being used for drop tube experiments and includes the electromagnetic levitation furnace and the electron beam furnace. We did spend considerable effort working with Dr. John Perepesko's group at the University of Wisconsin Vanderbilt University to process some of their NiV, Ni, and Cu samples.

2.1.2. UAH is fortunate to continue with experienced personnel with no extended down times and has continued to maintain a productive capability. As an example of the continued progress made in the productivity of the Drop Tube the chart below lists the number of Drop tube experiments made at the facility during FY90 in comparison with the previous two years.

#### **DROP TUBE PRODUCTIVITY**

<b>YEAR</b>	<b>1988</b>	<b>1989</b>	<b>1990</b>	<b>1991</b>	<b>1992</b>
<b>TOTALS</b>	404	315	472	450	657

Figure 1. Histogram from the above data showing the numbers of Drop Tube Experiments performed from 1988 - 1992.

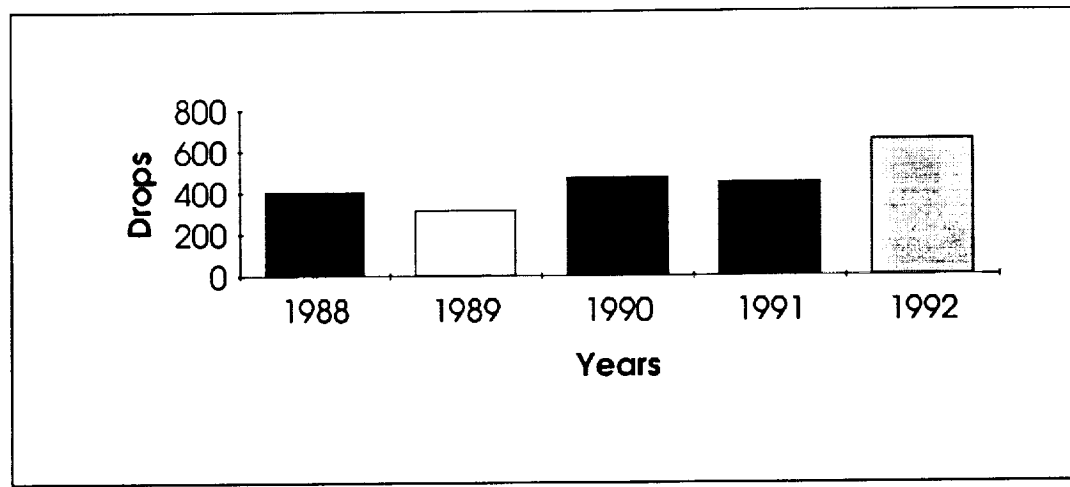


Figure 1 shows a histogram of the drop distribution from the above table. The reason for the smaller number of drops in FY89 was due to a decrease in the number requested by the Vanderbilt University group. In FY90, the primary interruptions were the use of the drop tube for a tethered satellite test in January and maintenance and set-up for the Nb drops for Dr. Mike Robinson.

2.2.0 UAH has developed procedures delineating the objectives, test sequences, operational timeline, etc. prior to each experiment or experiment series. This has included ground-based checkout of experiment apparatus and support systems, both for pre-flight, flight and ground control, and installing and testing suitable apparatus in the facilities in order to provide the appropriate processing conditions required for the experimental work. UAH has recorded and analyzed experiment apparatus operation parameters and thermal profiles as appropriate to interpret results of the experiments during the contract period. Existing apparatus such as E-beam furnaces, dropper furnaces, and levitation devices have been made available to any experimenter wishing to use the Drop Tube on an "as available" basis. Scheduling of apparatus and facilities has been done through the designated MSFC coordinator, Dr. Michael Robinson of SSL.

2.2.1. UAH personnel have continued to work on performing tests and check-outs on all facilities as part of the facilities requirements. The Drop Facilities need extensive mechanical and electrical preventative maintenance, which UAH is not authorized to perform. SSL does provide technician support for this activity. This arrangement works well, since the technician can interface more easily with MSFC facilities and supply personnel than the University personnel can.

2.3. UAH has worked closely with the MSFC and other personnel who have shown interest or have supplied materials for processing at the Drop Tube in providing consultation and expert interpretation of experiment results in the area of undercooling, nucleation, immiscible metals, electromagnetic levitation, metallurgy, and chemical processes.

2.3.1. After the experiments were performed, each scientific investigator for each facility or experiment received their samples, the data derived from each experiment, and any additional comments which might assist in the interpretation of the experiment. For the Drop Tube this data set includes pyrometer data, pressure measurements and electrical parameters affecting the molten droplet.

2.3.2. In general other than tour groups visiting the Drop Facilities and the UAH laboratory, we have not been requested by too many outside groups to provide expertise on low gravity materials processing. Due to the nature and the diversity of the many experiments we perform at the various facilities, we feel that we should be more beneficial to the program than we currently have. An accumulation of knowledge from building many experimental packages at the various facilities is certainly useful in designing a scientific

experiment for space, that would benefit from preliminary experiments at any of the ground-based facilities. It would appear from our perspective that the many programs initiated by NASA for new hardware do not seem to follow a master plan. If such a plan existed it would certainly make it easier for groups such as ours to make inputs into the role that the ground-based facilities can play in the various materials processing programs.

2.4 Since the recording of droplet temperatures as a function of drop time in the Drop Tube is such an important part of most Drop Tube experiments, it is necessary to continue to search for and evaluate for the most cost effective method for determining transit droplet temperature along the length of the Drop Tube in order to make recommendations for implementation of such a method or methods. Upon specific direction procure, install and verify equipment and/or instrument required to implement the preferred method.

2.5 UAH has conducted various experimental drops, as directed, associated with operational readiness demonstrations of the drop tube facility and scientific investigations.

2.5.2. Over the years additional work and analysis have been performed by members of our group, Tom Rathz and Dr. William Kaukler and by others such as Dr William Hofmeister of Vanderbilt University. Alternatives included high gain Si detectors, temperature stabilized Si detector and logarithmic amplifiers. Tom Rathz has continued development of quartz light-pipes at the Drop Tube and a blackened stove-pipe arrangement in the Drop Tube, thereby increasing the quantity of radiance from recalescence and decreasing the amount of scattered light collected by the detectors. They see noticeable improvements in the S/N level of these signals. This approach should also be very useful for improving data obtained from lower melting materials.

2.7.3 Tom Rathz has been able to participate to some extent with the Non-contact Temperature Measurement Working Group. Thus he is able to at least keep abreast of other techniques which are being considered in NASA's various programs.

2.5. Upgrade Drop Tube and Drop Tower experiment apparatus capability through continual evaluation of experiment and operational requirements.

2.5.1. In addition to the detectors required for temperature measurement of falling drops, UAH personnel have made a number of improvements to increase the productivity of the

Tube and improve upon the data collection process for the facilities. Continual up-grading of the software supporting High Speed Data Acquisition systems which includes support for the Nicolet Transient Digitizer interfaced to the silicon detectors along the tube. In addition we have maintained the video capability to observe samples during the sample heating and melting periods in the belljar. These systems are still working quite well. We are also still using an optical disk for archiving drop tube data. A number of modifications have been made to improve upon the ease of sample changing in both the belljar and the catch tube. These modifications have been instrumental in improving control of samples during processing and quicker turn-around time in running experiments.

An improved electron beam system was designed and fabricated by Gary Williams. It has been very productive. Part of the improvement in quantity of drops made this year may be due to the increased productivity of that particular system.

2.5.2 New work on providing finite difference simulations for predicting temperature gradient changes in the falling drops were also started in this past year. The software Phoenix, which had been used earlier for predicting the effect of gravity on convective flows for a KC-135 experiment, was used in this work. Interestingly enough, the model predicts that for a molten metal, such as zirconium shown here, if the starting temperature gradient is about 100 ° C from top to bottom, then a symmetric distribution of temperature is attained within 120 - 140 milliseconds. Illustrations of the output from the model are shown in the following pages.

Figure 4(a) Initial temperature gradient

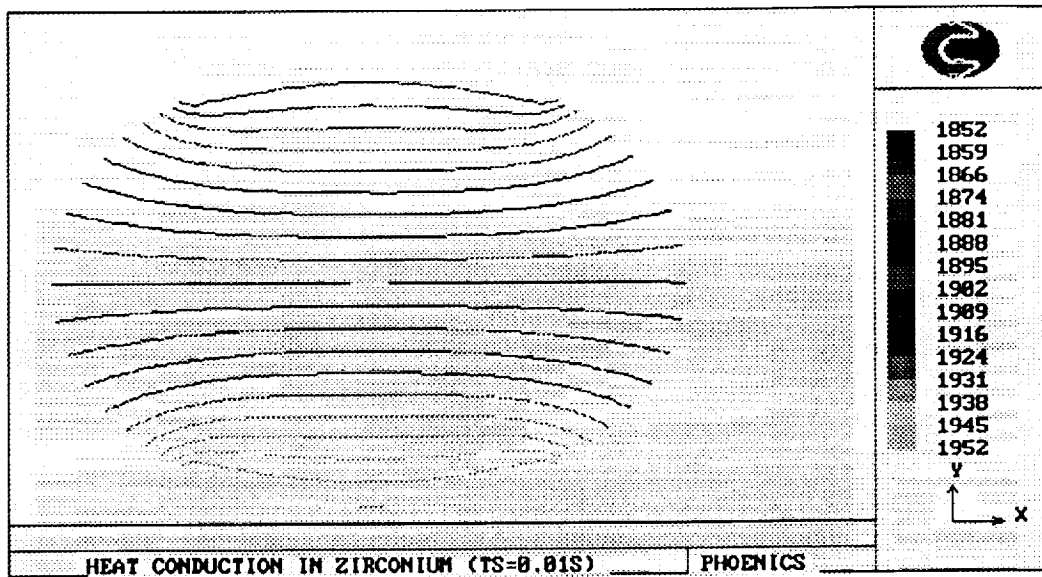


Figure 4(b) Temperature gradient after 0.01 seconds

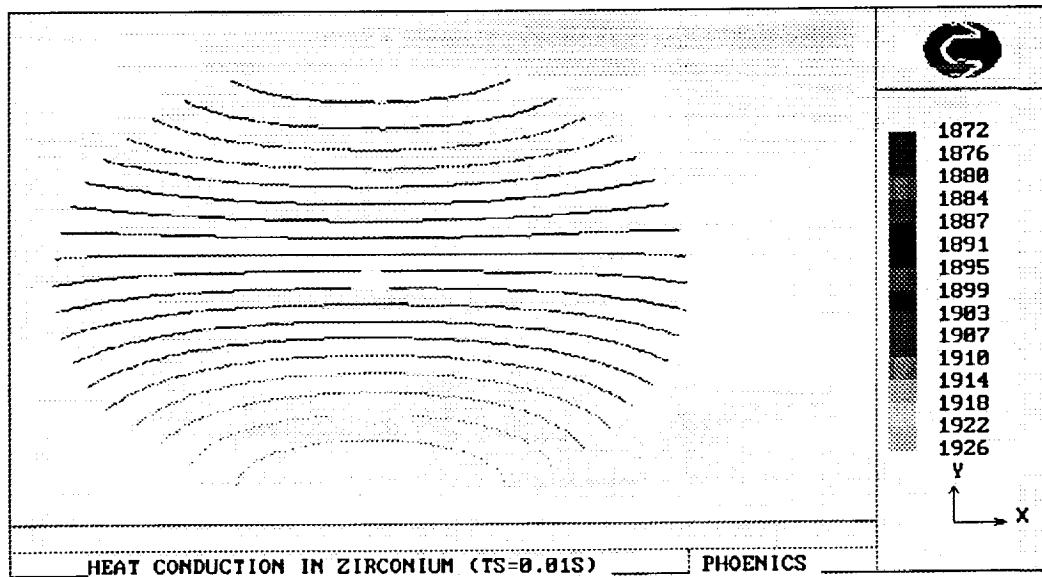


Figure 4(c) Temperature gradient after 0.02 seconds

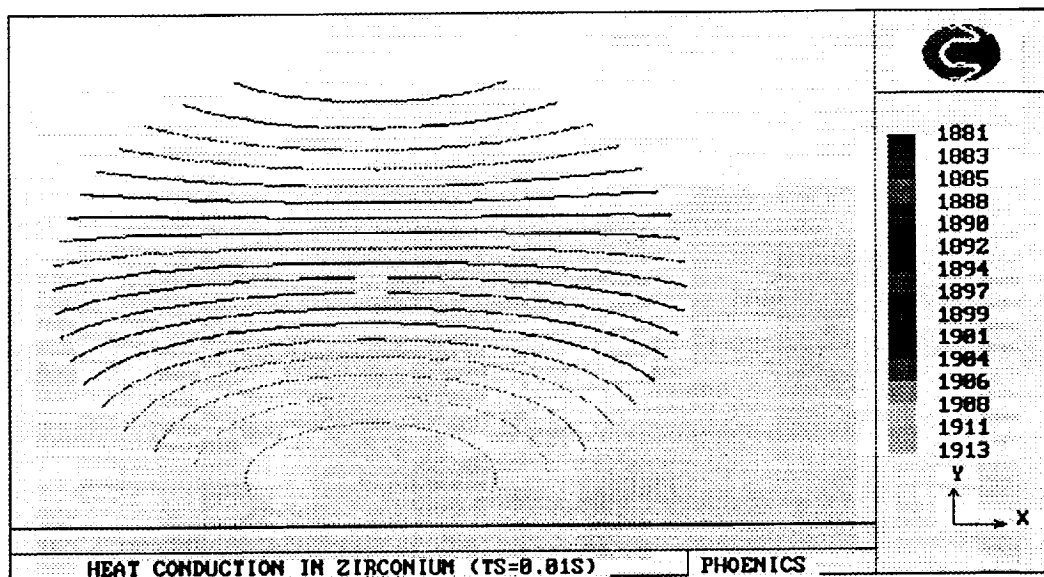


Figure 4(d) Temperature gradient after 0.03 seconds

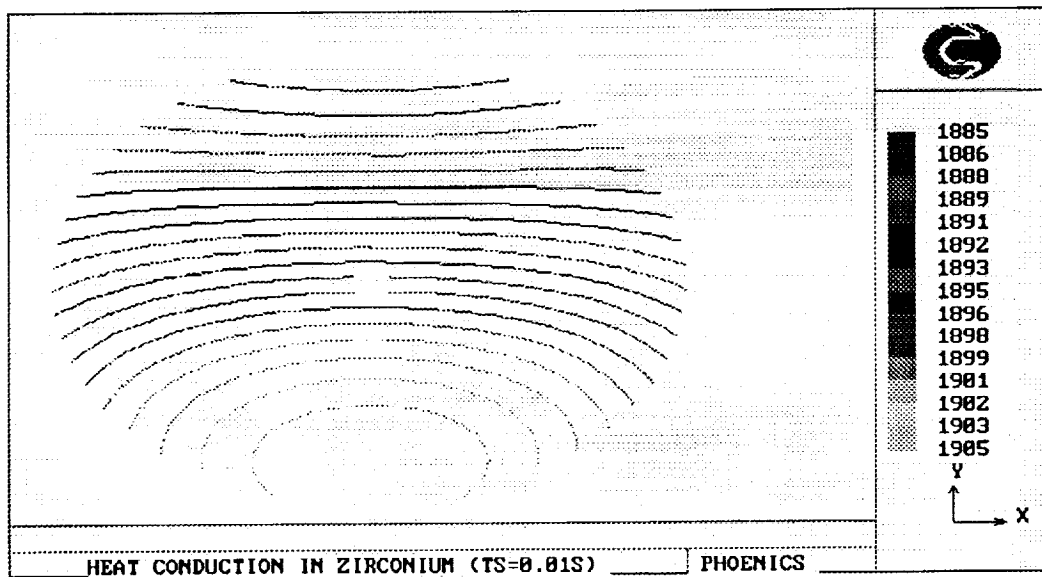


Figure 4(e) Temperature gradient after 0.04 seconds

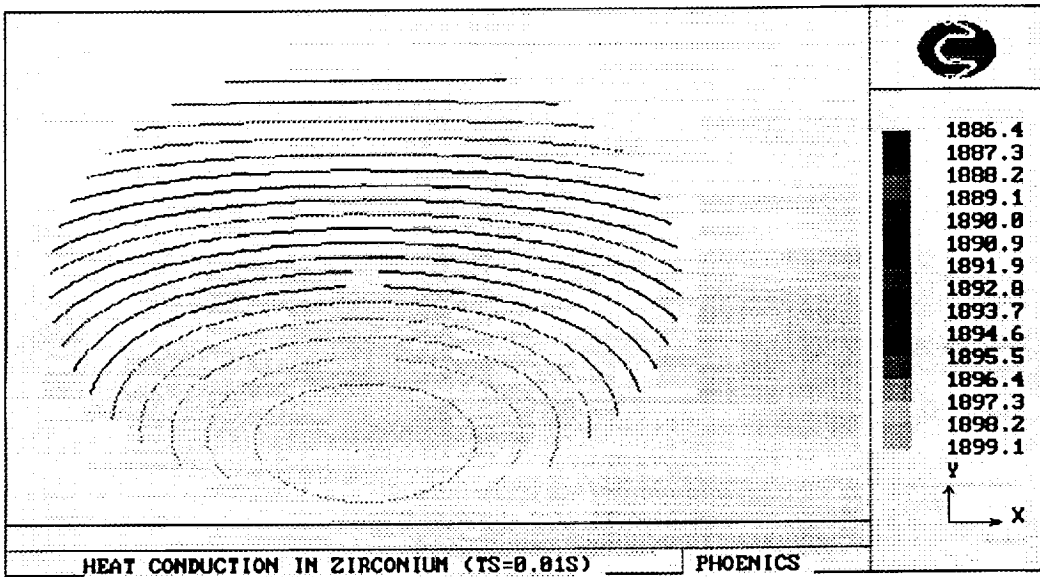


Figure 4(f) Temperature gradient after 0.05 seconds

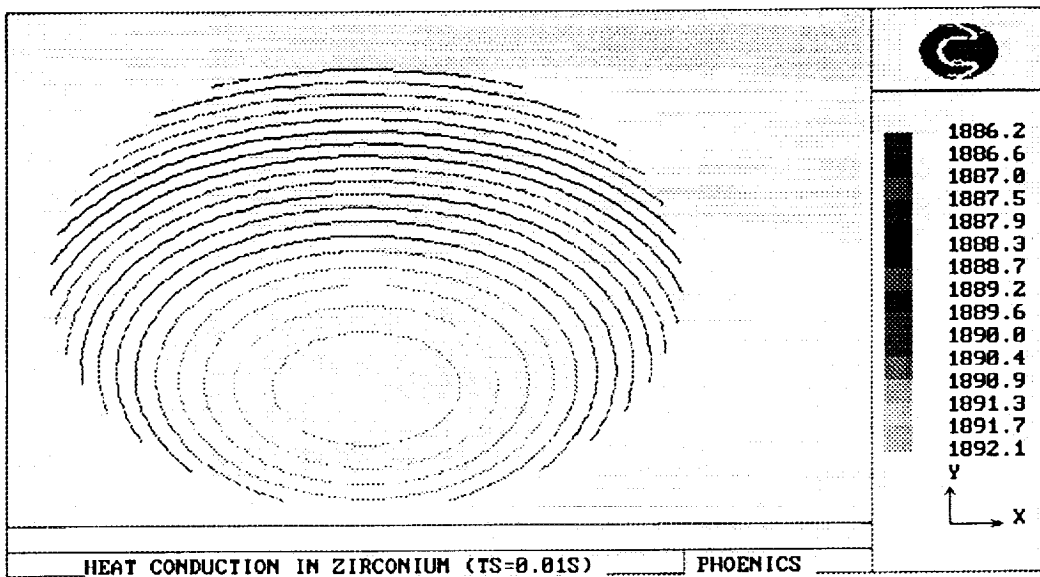


Figure 4(f) Temperature gradient after 0.06 seconds

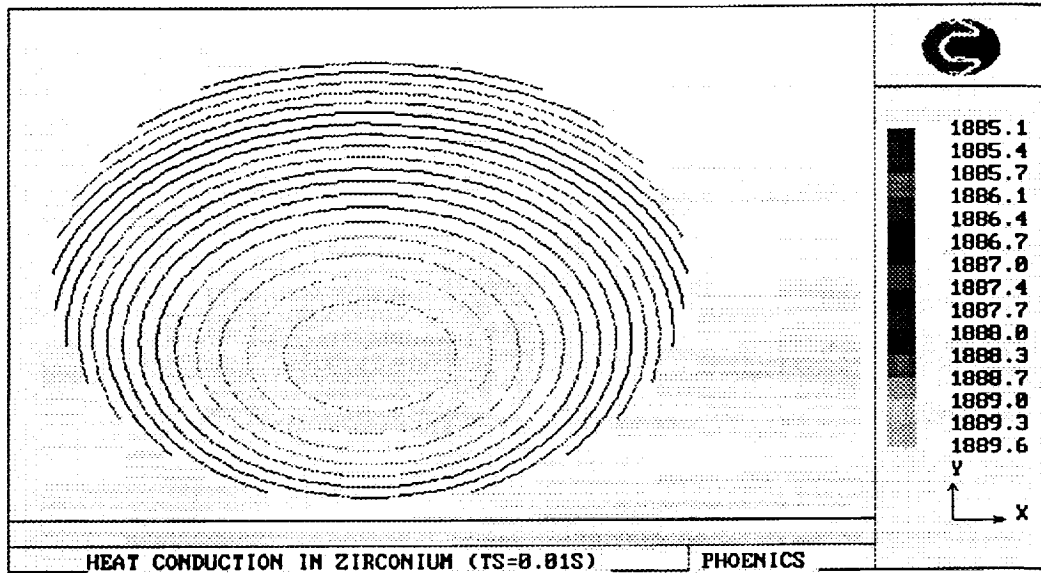


Figure 4(g) Temperature gradient after 0.07 seconds

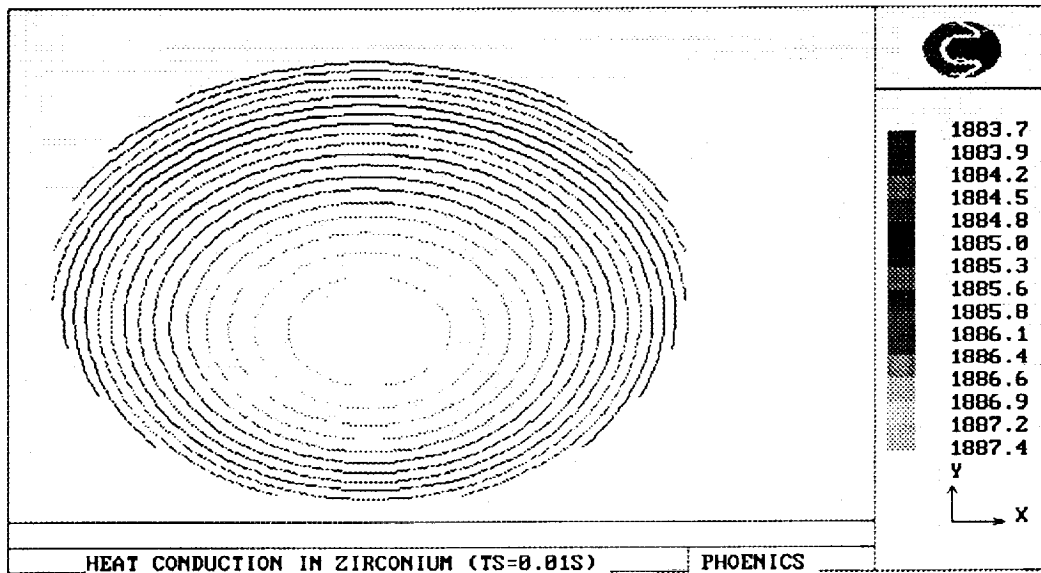


Figure 4(h) Temperature gradient after 0.08 seconds

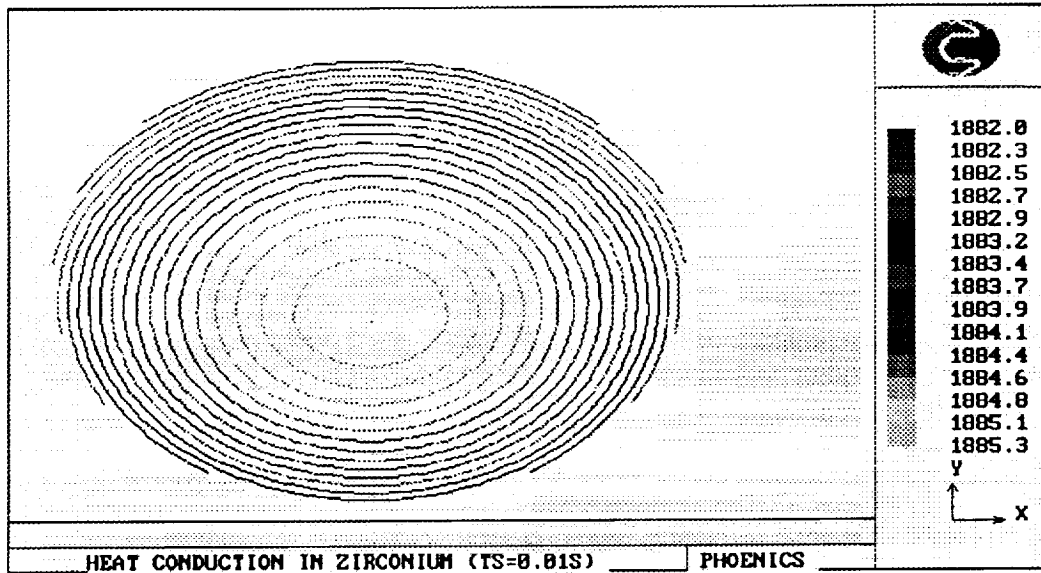


Figure 4(i) Temperature gradient after 0.09 seconds

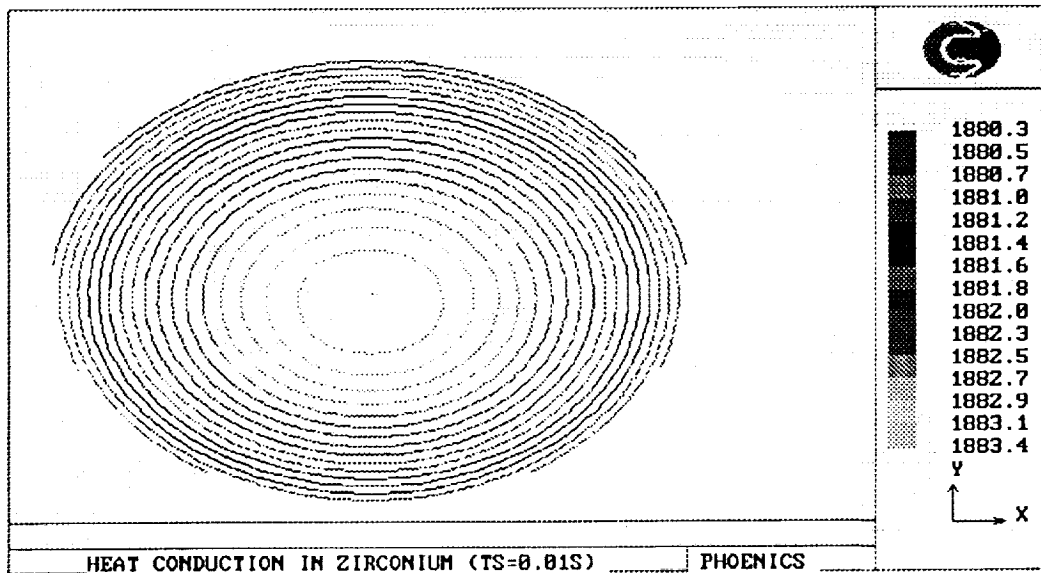
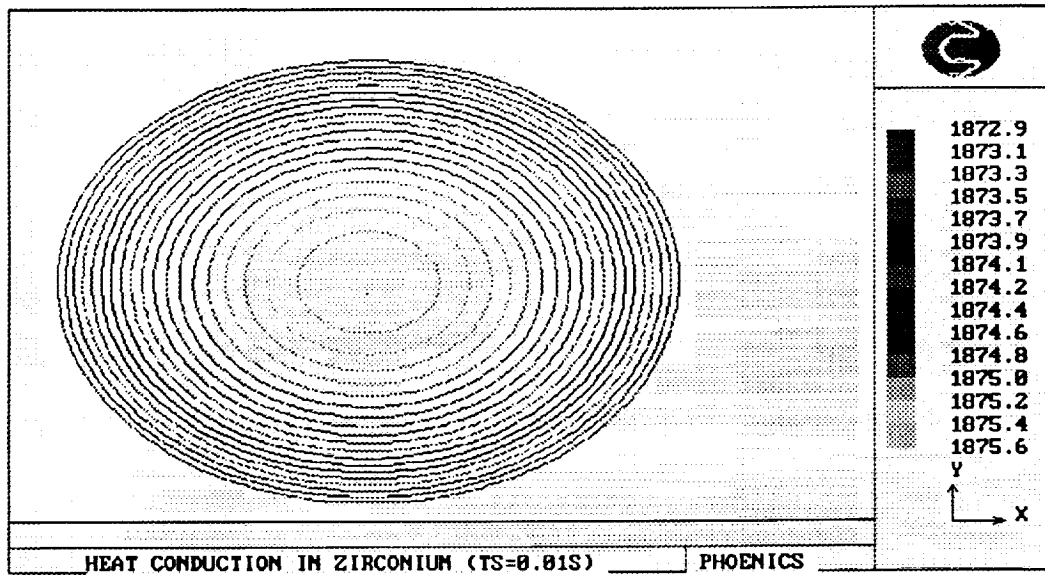


Figure 4(j) Temperature gradient after 0.14 seconds



### 3.0. Acknowledgements

The work performed on this contract was successful due to the fact that many people were able to provide help and assistance in meeting the above goals. This includes Dr. Mike Robinson as TCOR for the contract and coordinator for the Drop Tube and Kevin Vellacott-Ford at the Drop Facilities, and of course, the many UAH personnel who have worked with us to ensure that the research objectives were attained.

